

## CLAIMS

What is claimed is:

1. A system for detecting a violation of a traffic signal at an intersection comprising the steps of:

5       a virtual violation line interface for receiving from a user data defining a virtual violation line that corresponds to a location at said intersection that if crossed by a vehicle entering said intersection during a red light phase of said traffic signal, is indicative of a violation of said  
10       traffic signal by said vehicle;

      a storage device for storing a representation of said intersection and said virtual violation line;

      at least one camera for capturing at least one image of a vehicle at said intersection;

15       a processing unit operative to:

      analyze said at least one image to identify a position of said vehicle with respect to said virtual violation line,

      compare said position of said vehicle to said  
20       virtual violation line, and

      generate an indication of a violation in the event said processing unit determines that said position of said vehicle is beyond said location and that said vehicle has traveled into said intersection during said  
25       red light phase of said traffic signal.

2. The system of claim 1 wherein said at least one camera is further operative to capture a plurality of images of said vehicle approaching said intersection; and

30       said processing unit is operative to analyze said plurality of images of said vehicle and to generate a

prediction signal in the event it is determined by said processing unit that said vehicle is likely to violate said red light phase of said traffic signal.

5     3. The system of claim 2 further including an additional signaling device for cross traffic approaching said intersection from a direction other than said vehicle, said additional signaling device responsive to said prediction signal for signaling said cross traffic not to enter said  
10 intersection.

4.     The system of claim 3 wherein said additional signaling device comprises an additional traffic signal and said additional traffic signal is responsive to said prediction  
15 signal to delay a green light phase of said additional traffic signal.

5.     The system of claim 1, wherein said at least one camera comprises at least one video camera.  
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6.     The system of claim 1, wherein said at least one camera comprises at least one digital camera.

7.     The system of claim 1, wherein said processing unit  
25 comprises at least one microprocessor.

8.     The system of claim 2, wherein said processing unit is further responsive to a time remaining in a yellow light phase of said traffic signal in the generation of said  
30 prediction signal.

9. The system of claim 2, wherein said processing unit is operable to determine a current speed for said vehicle and to utilize said current speed in determining whether to generate said prediction signal.

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10. The system of claim 2, wherein said processing unit is operable to determine a current acceleration for said vehicle and to utilize said current acceleration in determining whether to generate said prediction signal.

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11. The system of claim 10, wherein said processing unit is operable to compute a time remaining before said vehicle reaches said location corresponding to said virtual violation line responsive to said determination of said  
15 current acceleration.

12. The system of claim 11, wherein said processing unit is operable to calculate a deceleration required for said vehicle to stop within said time remaining before said  
20 vehicle reaches said location corresponding to said virtual violation line.

13. The system of claim 12 wherein said processing unit is operable to determine whether said required deceleration is  
25 larger than a specified deceleration limit value, and if so, to generate said prediction signal.

14. The system of claim 1, wherein said virtual violation line is stored within said storage device a a portion of  
30 said representation of said intersection.

15. A method for detecting a violation of a traffic signal comprising the steps of:

storing in a storage device a representation of a traffic intersection, said representation of said intersection including a virtual violation line corresponding to a location at said intersection that if crossed by a vehicle entering said intersection during a red light phase of said traffic signal, is indicative of a violation of said traffic signal by said vehicle, said location of said virtual violation line with respect to said intersection being user configurable;

capturing at least one image showing said vehicle at said intersection;

analyzing said at least one image of said vehicle at said intersection to ascertain a position of said vehicle with respect to said location corresponding to said virtual violation line; and

generating an output indicative of a violation of a red light phase of said traffic signal in the event said analyzing step indicates that said vehicle has travelled beyond said location corresponding to said virtual violation line and into said intersection during said red light phase of said traffic signal.

25 16. The method of claim 15, further comprising the steps of:

capturing a plurality of images showing said vehicle approaching said traffic signal; and

generating a prediction signal, responsive to said plurality of images, and an indication of a current traffic signal light phase, in response to a determination that said

vehicle is likely to violate said red light phase of said traffic signal.

17. The method of 16, further including the step of signaling cross traffic approaching said intersection from a direction other than said vehicle not to enter said intersection responsive to said prediction signal.

18. The method of claim 17 wherein said step of signaling said cross traffic includes the step of delaying a green phase of a traffic signal for said cross traffic.

19. The method of claim 15, wherein said capturing step comprises the step of capturing said at least one image with a video camera.

20. The method of claim 15, wherein said capturing step comprises the step of capturing said at least one image with a digital camera.

21. The method of claim 16, wherein said step of generating said prediction signal includes the steps of:

determining a time remaining for said vehicle in a yellow light phase of said traffic signal; and  
generating said prediction signal, based in part, upon said time remaining in said current yellow light phase.

22. The method of claim 16 wherein said step of generating said prediction signal includes the steps of:

determining from said plurality of images a current speed for said vehicle; and

generating said prediction signal, based in part, upon said current speed of said vehicle.

23. The method of claim 16, wherein said step of generating  
5 said prediction signal includes the step of generating from said plurality of images a current acceleration for said vehicle and

said step of generating said prediction signal is based in part upon said current acceleration of said vehicle.

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24. The method of claim 16, wherein said step of generating said prediction signal further includes the step of generating a time remaining before said vehicle crosses said location corresponding to said virtual violation line and  
15 said step of generating said prediction signal is based, in part, upon said time remaining.

25. The method of claim 16, wherein said step of generating said prediction signal includes the step of:

20 calculating a rate of deceleration that is required for said vehicle to stop before said location corresponding to said virtual violation line; and

generating said prediction signal in the event said required rate of deceleration is greater than a  
25 predetermined deceleration limit value.

26. The method of claim 15, wherein said storing step comprises the step of storing in said storage device a representation of said virtual violation line that  
30 corresponds to a location beyond an actual stop line for a lane of traffic in which said vehicle is travelling.

27. The method of claim 15, wherein said storing step includes the step of storing said representation of said virtual violation line for locations corresponding to each  
5 of a plurality of lanes of traffic approaching said intersection.

28. The method of claim 27 further including the step of identifying which one of said plurality of lanes of traffic  
10 said vehicle is travelling in from an analysis of said at least one image.

29. A collision avoidance system for a first traffic signal having a current light phase equal to one of the set  
15 consisting of at least red and green and a second traffic signal having a current light phase equal to one of the set consisting of at least red and green, comprising:

at least one violation image capturing device;

a plurality of showing at least one vehicle approaching  
20 said first traffic signal, said images derived from an output of said violation image capturing device;

a processing unit responsive to said plurality of images and an indication of said current first traffic signal light phase, for generating at least one violation  
25 prediction for said at least one vehicle approaching said first traffic signal, said violation prediction indicating a likelihood that said at least one vehicle approaching said first traffic signal will violate an upcoming red light phase of said first traffic signal;

a collision avoidance unit responsive to said violation prediction, for asserting at least one violation predicted signal; and

5 a traffic light controller for said second traffic signal for controlling said second traffic signal responsive to said violation predicted signal in order to signal traffic approaching said second traffic signal not to enter said intersection;

10 said processing unit further operative to, maintain a virtual violation line, derive a position of said at least one vehicle from at least one of said plurality of images, compare the position of said vehicle to said virtual violation line, and generate a confirmation signal indicative of a red light violation in response to a  
15 determination that said at least one vehicle has crossed said virtual violation line during said red light phase of said first traffic signal.

20 30. The system of claim 29, wherein said violation capturing device comprises at least one video camera.

31. The system of claim 29, wherein said violation image capturing device comprises at least one digital camera.

25 32. The system of claim 29, wherein said collision avoidance unit comprises software executing on a processor.

33. The system of claim 29, wherein said processing unit comprises software executing on a processor.

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34. The system of claim 29, wherein said processing unit is responsive to vehicle locations provided by a tracker unit.

35. The system of claim 29, wherein said processing unit is further responsive to a time remaining in yellow light phase input.

36. The system of claim 29, wherein said processing unit is further operable to determine a current speed for said at least one vehicle.

37. The system of claim 29, wherein said processing unit is further operable to determine a current acceleration for said at least one vehicle.

38. The system of claim 29, wherein said processing unit is further operable to compute a time remaining before one of said at least one vehicle enters said traffic intersection, responsive to determination of a current acceleration of said vehicle.

39. The system of claim 38, wherein said processing unit is further operable to calculate a deceleration required for said at least one vehicle to stop within said time remaining before said vehicle enters said traffic intersection.

40. The system of claim 39 wherein said processing unit further operative to determine whether said required deceleration is larger than a specified deceleration limit value, and if so, updates a violation prediction value for the current frame to indicate that a violation is predicted.

41. The system of claim 29, wherein said virtual violation line is maintained by said processing unit as a portion of an internal representation of said intersection.

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42. The system of claim 41, wherein said virtual violation line is represented within said processing unit as being located beyond an actual stop line within a respective lane of said internal representation of said intersection.

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43. The system of claim 29, wherein said traffic light controller is responsive to said violation prediction to extending said red light phase of said second traffic signal.

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44. A method of collision avoidance at an intersection for a first traffic signal having a current light phase equal to one of the set consisting of at least red and green and a second traffic signal having a current light phase equal to one of the set consisting of at least red and green, comprising:

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capturing a plurality of images showing at least one vehicle approaching said first traffic signal, said images derived from an output of a violation image capturing device;

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maintaining at least one virtual violation line at an intersection for said at least one vehicle approaching said first traffic signal;

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generating, responsive to said plurality of images and an indication of said current first traffic signal light phase, at least one violation prediction for said at least

one vehicle approaching said first traffic signal, said violation prediction indicating a likelihood that said at least one vehicle approaching said first traffic signal will violate an upcoming red light phase of said first traffic  
5 signal;

asserting, responsive to said violation prediction, at least one violation predicted signal coupled to said second traffic signal;

controlling, responsive to said violation predicted  
10 signal, said second traffic signal in order to signal traffic approaching said second traffic signal not to enter said intersection;

generating from at least one of said plurality of images a location of said at least one vehicle with respect  
15 to said virtual violation line;

comparing said location of said at least one vehicle to a position defined by said virtual violation line; and

generating an output indicative of a red light violation of said first traffic signal in the event said  
20 location of said vehicle is determined to be beyond said position of said virtual violation line within said intersection during said red light phase of said first traffic signal.

25 45. The method of claim 44, wherein said violation image capturing device comprises at least one video camera.

46. The method of claim 44, wherein said violation image capturing device comprises at least one digital camera.

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47. The method of claim 44, further including the steps of:

determining a time remaining in a current yellow light phase; and

generating said at least one violation prediction in response to said time remaining in said current yellow light phase.

48. The method of claim 44, further including the steps of:

determining a current speed for said at least one vehicle; and

generating said at least one violation prediction in response to said current speed of said at least one vehicle.

49. The method of claim 44, wherein said step of generating said at least one violation prediction includes the step of determining a current acceleration for said at least one vehicle.

50. The method of claim 44, wherein said step of generating said at least one violation prediction includes the step of computing a time remaining before said at least one vehicle enters said traffic intersection.

51. The method of claim 50, wherein said step of generating said at least one violation prediction further includes the step of calculating a rate of deceleration required for said at least one vehicle to stop within said time remaining before said vehicle enters said traffic intersection.

52. The method of claim 51 wherein said step of generating said at least one violation prediction includes the step of determining whether said required deceleration is larger

than a specified deceleration limit value, and if so, updating a violation prediction value for the current frame to indicate that a violation is predicted.

5 53. The method of claim 44, wherein said step of maintaining said virtual violation line includes the step of maintaining said virtual violation line as a portion of a representation of said intersection.

10 54. The method of claim 53, further including the step of maintaining said virtual violation line at a location beyond an actual stop line within a respective lane of said representation of said intersection.